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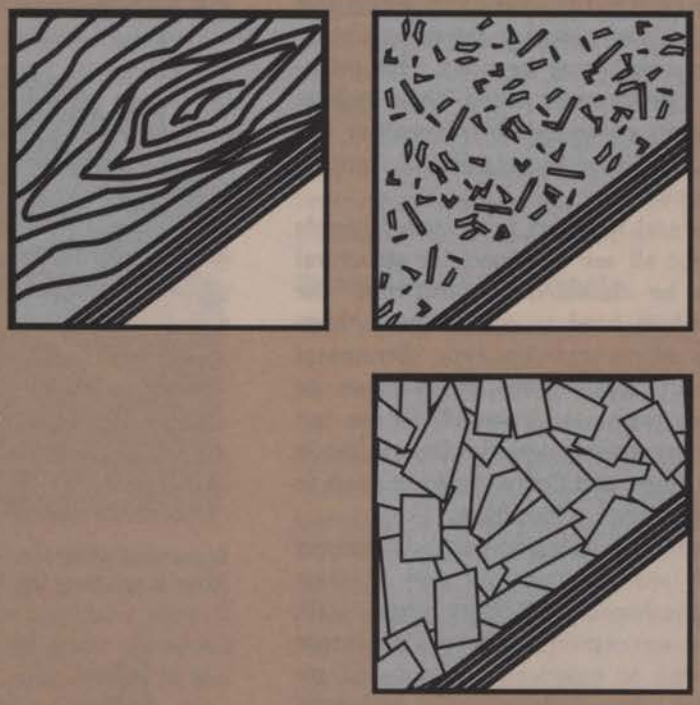
Structural Panels



Council Notes
Building Research Council

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College of Fine and Applied Arts-University of Illinois

Introduction

This publication deals with wood-based, composite structural panel materials. A composite product is a combination of two or more parts to achieve new or unique properties or to meet certain structural requirements for applications such as floor decking and wall and roof sheathing.

These structural panel products are manufactured in a variety of ways: as laminated veneers to produce plywood; as non-veneer structural panels from flakes or longer strands; and as composites with particleboard cores and veneer faces. Because each panel poduct is made using a different process and different wood components and glues, the only way to compare them accurately is to describe how they may be used. This information is called a *performance rating*. These ratings include the amount of exposure to weather the panel will withstand, and the maximum framing spacing for various uses.

There are several types of non-veneer panels produced, but not all are designed for structural applications. To be classified as structural, the binders or adhesives used to manufacture these panels must be of an exterior type. Structural panels are usually made from large flakes or elements, such as wafers and strands. These can be compared to non-structural particleboards, made from very small chips and flakes, that are used as floor underlayment and in furniture.

The first commercially produced non-veneer structural panel was designed for use as floor decking for mobile homes and other factory-built construction. The newer panels generally use larger flakes, bonded with an exterior adhesive, and are made mostly for use as floor, wall, and roof sheathing in light-frame construction. These newer products are gradually replacing plywood for sheathing purposes. There are, at present, three types of non-veneer structural panel products: waferboard, oriented strandboard, and up-graded conventional particleboard. These are marketed under various trade names. In addition, Comply® is a composite structural panel consisting of veneer faces and a core of structural particleboard.

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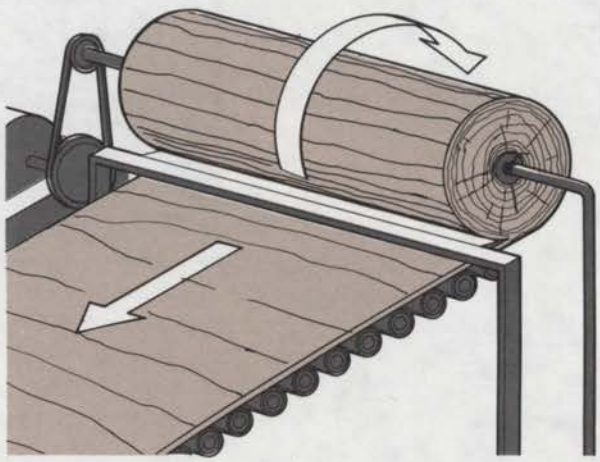
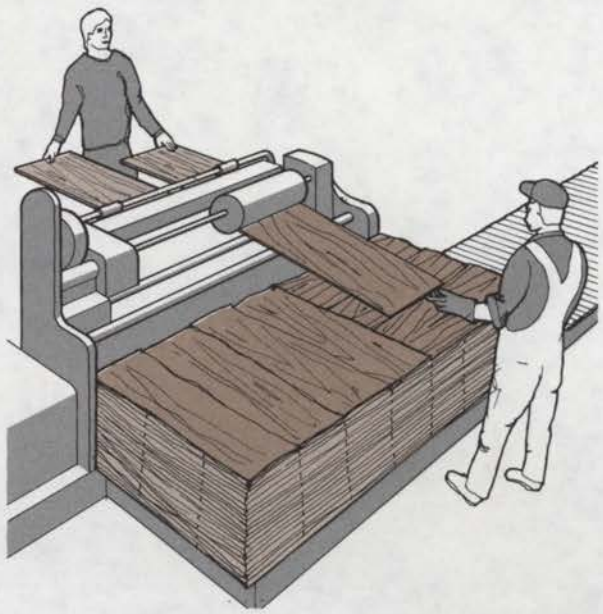
PLYWOOD

Plywood is the best known structural panel. It is made with an odd number of layers of wood glued together with the grain of the adjacent layers at right angles to each other to provide stability and to minimize dimensional changes. The grain of the outer two plies runs in the same direction. Customarily, softwoods have been used in construction plywood; however, some hardwood species are now being used. These veneers are peeled from the logs. Decorative plywood is usually made from hardwood veneers that have been sliced from the logs. Such material is seldom used in structural applications.



Structural plywood is made from thin veneers peeled from a rotating log by a sharp blade.



The plywood veneers pass through a glue spreader and are stacked in crossed layers. The stack is then pressed and heated to cure the glue, and the finished sheets trimmed to size.

Construction plywood is normally used for structural purposes in light-frame building, and is also used for cabinet work, furniture, and interior paneling. Plywood has traditionally been classified as to panel grade and ability to withstand weathering, and manufactured according to U.S. Product Standard PS 1-83 for Construction and Industrial Plywood. More recently, an alternative classification process has been introduced — namely, wood-based panels performance-rated for specific uses.

Product Standards

According to the Product Standard PS 1-83, plywood panels are manufactured to prescribed minimum requirements. These pertain to acceptable wood species, definition of veneer grades for the individual plies, and composition of the individual plies in a sheet. The plies or veneers are qualified by the grade of the veneer with N (best), A, B, C, and D (poorest). N-grade is a special-order veneer where a natural finish is to be used. An A-A grade sheet would have both faces of A-quality; in C-D grade, one face is of C-quality and the other of D-quality. Only minor surface defects and limited patches are permitted in A-quality, and the face is sanded. Grade B allows some appearance defects and permits more patching than grade A. Grades C and D permit knots, knotholes, and splits, with larger defects allowed in the D grade. A special C-grade plywood is produced that has the surface defects repaired for use as underlayment.

The interior plies may be of any grade, although D is commonly used for the inner plies of interior-type plywood. The lowest grade permitted in exterior-type plywood is C, and defects in the inner plies of marine plywood for boat hulls must be patched and repaired. The end use of the plywood will determine the selection of the proper grade. Grade A-A might be selected where appearance is a factor and it is desirable that both outer plies be free of unrepaired defects, as for boat hulls, cabinet doors, or decorative use. At the other end of the scale, C-D grade plywood, for example, is manufactured with exterior adhesives and is used for wall and roof sheathing. It also may be pressure-treated with preservative chemicals for use in wood foundations.

The grain of successive plies in plywood is at right angles to the adjacent ply, except in the case of four-ply, where the grain of the center two plies runs in the same direction and across that of the face plies.

Southern pine is a very common plywood veneer, especially in the eastern part of the country. Other species used include Douglas fir, Western larch, Western hemlock, Sitka spruce, commercial white firs, Alaska and Port Orford cedar, California redwood, and, more recently, yellow poplar and sweetgum.

Plywood panels manufactured under PS 1-83 may be span-rated in accordance with prescriptive requirements, or on the basis of performance tests similar to those described below.

Performance-Rated Panels

The newer performance standards set requirements that a panel must satisfy to be approved for a specific use. The method of manufacture is not specified, but the panel is made to meet a specific set of requirements. The American Plywood Association has developed performance standards to qualify wood-based panels for use as roof and wall sheathing, subfloor, and combination subfloor and underlayment. As the standard is now written, the requirements and test methods are the same for nearly all types of panels, both plywood and non-veneer.

From a group of panels submitted by the manufacturer, the certifying agency selects and tests several for structural strength. This includes the ability to support uniform, concentrated, and impact loads, and the ability to hold fasteners. Based on the test results, a span rating is assigned to that panel. A number such as 24/16 on the panel indicates that when used as roof sheathing, the framing should be no more than 24 inches on center, and if used for subfloor, the framing or supports should be no more than 16 inches on center. At the same time, samples are laboratory-tested for certain properties that can be used for quality control in the manufacturing process.

The testing methods used are a combination of ASTM standard tests and specialized tests developed by APA. These tests are detailed in NRB Report 108 of the National Evaluation Service to the Council of American Building Officials. Therefore, plywood panels manufactured under this standard and carrying the APA trademark are

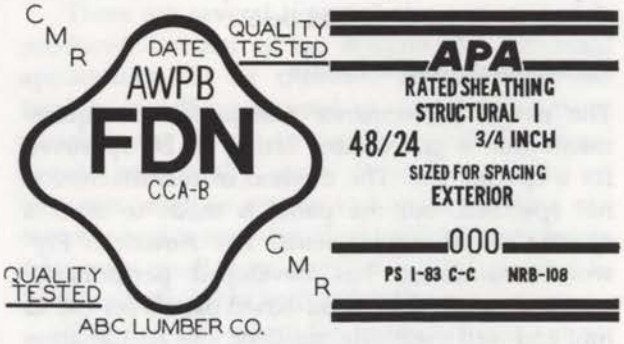
recognized by the three major building code organizations: Building Officials and Code Administrators International (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International (SBCC).

Size

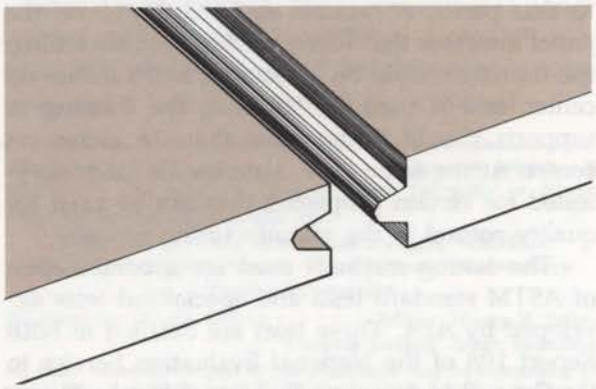
Structural plywood is most readily available in panels 48″ wide and 96″ long. Other lengths and widths are produced, but are not regularly stocked by most lumberyards. Plywood is also produced with tongue-and-grooved edges, especially for use as a combination subfloor and underlayment.

Thickness

Structural plywood is manufactured in thicknesses of ¼″ to 1⅛″. Until recently, thickness varied over this range by ⅛″ increments; however, three new panel thicknesses, $^{15}/_{32}$″, $^{17}/_{32}$″, and $^{23}/_{32}$″ have been added. Structural plywood was originally produced with five plies for the common thicknesses; however, there are mills producing ½″ and ⅝″ plywood with three plies or with two plies in the core running in the same direction (four-ply).



The grade stamps on the structural panels indicate their strength and use. The stamp on the right indicates that it can be used as roof sheathing with framing spaced 48″ on center or as subfloor with framing spaced 24″ on center, and that the sheet has been sized to allow for spacing between sheets. The stamp on the left indicates a product that has been pressure-treated with preservatives suitable for use in wood foundation systems.



Products with tongue-and-groove edges are often used for subflooring, since there is continuous support for the edges of the sheets.

Durability

All plywood and other wood-based structural panels, which will be discussed later, are classified according to durability or exposure to weather or moisture. Plywood can be manufactured either according to U. S. Product Standard PS 1-83 or the performance standards developed by the American Plywood Association. The exposure classifications used with each manufacturing standard are discussed briefly in the following sections.

PS 1-83. The traditional way of indicating the resistance of plywood to moisture is to separate it into two types — *interior* and *exterior.* The specification for exterior-type plywood requires that all glue lines be 100% waterproof (phenolic or resorcinol adhesive) and that all plies be of C-grade or better. *Marine* plywood is an upgraded exterior-type panel with additional limitations on species of wood and manufacturing details.

Interior-type plywood may be bonded with partially water-soluble adhesives, which will deteriorate or dissolve from exposure to excessive moisture or water. It is used in protected areas such as paneling and cabinets.

The common *CDX* plywood is a combination of both types. It is manufactured with one face ply of C-grade veneer and the remaining plies of D-grade. Since it has a D face, it must be classified as an interior-type panel. However, it is made with a waterproof adhesive. It is widely used for wall and roof sheathing and as a general utility material.

Performance-Rated. Performance-rated panels can be manufactured to meet one of four exposure durability classifications: *Exterior; Exposure 1; Exposure 2;* and *Interior. Exterior* is used where there is permanent exposure to moisture or weather. *Exposure 1* is used where long construction delays may occur, such as where the subfloor is exposed to the weather before the roof is constructed. *Exposure 2* indicates plywood that has been made with an intermediate-type adhesive, and is used where moderate construction delays are expected or where there is occasional exposure to high humidity or water leakage. *Interior* classification is for panels manufactured with water-soluble glue and intended for interior applications only.

Exterior panels in both manufacturing standards are equivalent. Exposure 1 is equivalent in durability to the common CDX plywood panel.

Treated Plywood

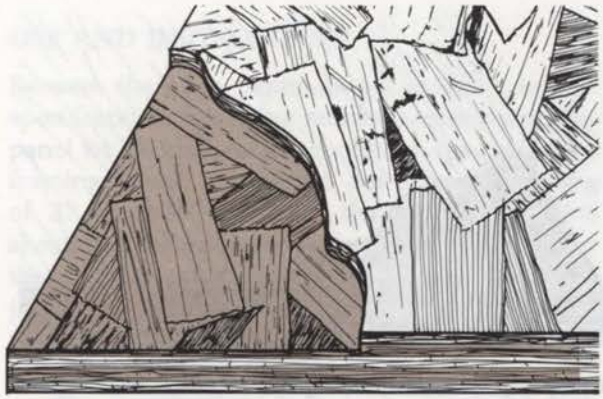
To date, plywood is the only structural panel authorized to be pressure-treated with fire-retardant or preservative chemicals. For either treatment, the panels must be identified with the proper labeling and be either Exterior- or Exposure 1-type. Plywood treated with fire-retardants should be re-dried to an average moisture content of 15%. Plywood treated with water-borne preservatives should be re-dried to a maximum moisture content of 18%.

NON-VENEER STRUCTURAL PANELS

Any panel product made of wood particles whose primary function is to safely withstand design loads over the life of the structure is considered to be a non-veneer structural panel. Structural panels of several types have recently become common in light-frame construction, primarily as subfloor and as wall and roof sheathing. The development of structural panels as an alternative to plywood is the result of several factors. One is the reduced availability of the type and species of logs desirable for making plywood. The old-growth, large logs used in the past are rare, and the logs now being harvested are smaller, coming from second- and third-growth trees. The higher price of the desirable logs, plus the fact that non-veneer structural panels can be made from species for which there is low demand, such as spruce and aspen, has made them price-competitive. Non-veneer panels also require less skilled labor to make and are manufactured closer to the point of use, reducing transportation costs.

Waferboard

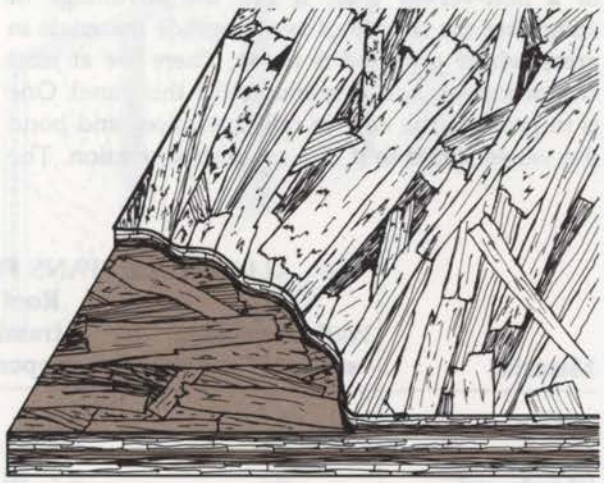
Waferboard is a structural panel product designed to be used in sheathing and general utility applications. Its only similarity to plywood is its sheet size and thickness. It has no veneer skins, but usually is made of aspen flakes which range in size from 1⅛″ to 3″, and are essentially rectangular in shape. The flakes are bonded with powdered phenolic resins and the assembly is formed in a heated press to the desired thickness. The flakes are randomly placed in the panel. Waferboard can be manufactured in sizes up to 8′ by 24′, and with tongue-and-groove edges. It is produced in thicknesses from ¼″ to ¾″. Some panels have a roughened surface for increased traction for carpenters working on steep roofs. Waferboard has less bending strength and stiffness than plywood, but it is being widely used in the United States and Canada as a sheathing material, with $\frac{7}{16}$″ waferboard being substituted for ⅜″ plywood.



Waferboard is made of thin wood flakes in a random pattern, with a resin binder. It has about the same strength in all directions.

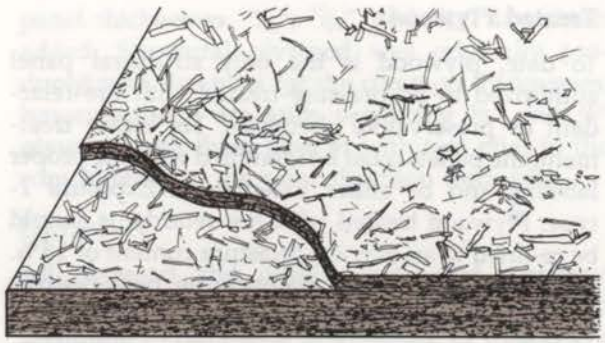
Oriented Strand Board

Oriented strand board (OSB) was developed to produce a composite panel with increased strength and stiffness. Particles used to make this panel are long and narrow (nominally, at least twice as long as wide) and are produced by slicing the wood across the grain. The strands are 2-3″ long and ¼″ to ½″ wide. These strands are placed in layers in the panel, with the outer layers running essentially parallel to the length of the panel, similar to the grain of the outer plies of plywood, and the inner layer crosswise. One major manufacturer does not cross-align the strands in the core layer. The strands are bonded with liquid phenolic resin and are hot-pressed to form the panel. The alignment of strands in a given layer increases the



Oriented strand board is made with longer, narrow wood chips. It is formed in layers, with the strands running approximately the direction of the length of the sheet at both surfaces and at right angles in the middle of the sheet. The panel is about twice as strong in bending along the length of the sheet and about the same along the width of the sheet as waferboard.

Comply® is a structural panel made with a wood veneer on both surfaces and a particleboard core.



Particleboard is formed of relatively small chips and strands of wood, bonded with resin. It has equal strength in both directions.

strength, stiffness, and dimensional stability in the direction of the orientation. OSB is made in thicknesses from ¼" to ¾". OSB is about twice as stiff in bending in the direction of the length of the panel and about the same in properties in the width direction as waferboard of the same density and thickness. The strength and stiffness properties are nearly the same as a plywood panel of the same thickness.

Recently, some waferboard manufacturers have developed a way to align specialized wafers, resulting in an oriented strandboard composition. Such products are marketed as oriented waferboard.

COMPLY®

Comply is a structural panel made with single layers of veneer, resin-bonded to the outer surfaces of a non-veneer core. It has the advantage of stretching the supply of veneer-grade materials in areas where plywood is made. There are at least two processes used to manufacture this panel. One is to produce the core in one operation, and bond the veneer faces to it in a separate operation. The other process produces the panel by placing the resin-coated particles on the bottom veneer, covering them with the top veneer, and hot-pressing the panel in one operation.

Building Code Acceptance

To obtain building code approval, plywood is manufactured according to U.S. Product Standard 1-83 or the performance standards developed by the American Plywood Association. For non-veneer structural panels, code approval has been on a company by company or proprietary basis, or, to an increasing extent, by the performance standards route administered by APA or other certifying agencies.

Allowable stresses for plywood manufactured according to PS 1-83 are available in the Plywood Design Specification published by the American Plywood Association. However, allowable stresses are seldom available for non-veneer structural panels. The table shows a comparison between panel products as found in building codes for roof, wall, and floor sheathing.

ALLOWABLE SPANS FOR STRUCTURAL PANELS

Material	Wall Sheathing studs 16" o.c.	Roof Sheathing framing 24" o.c. edge support	Roof Sheathing framing 24" o.c. no edge support	Subfloor joists 16" o.c.	Subfloor-Underlayment joists 24" o.c.
Plywood	5/16"	3/8"	1/2"	1/2"	3/4"
Comply	3/8"	3/8"	1/2"	1/2"	3/4"
Waferboard	3/8"	7/16"	9/16"	5/8"*	3/4"**
Oriented Strand Board	3/8"	3/8"	7/16"	7/16"	3/4"

* One manufacturer has received approval for ½" and another at 21/32".
** Not applicable for all waferboard applications.

Note: These panel thicknesses are for comparison purposes only, and are not applicable to all panel products of the same type. Oriented strand board, waferboard, and Comply are made to different engineering standards by various manufacturers; therefore, span capabilities may vary. Panels which have been tested, and which have code approval, will carry the APA stamp which gives the correct span information for that specific product.

SPECIAL PANELS

A number of specialty panels are manufactured that have the structural properties discussed previously but they have been modified for appearance or finishing. Several panel products have been grooved or otherwise decorated for use as a combination sheathing-siding material. Type 303 plywood is available with a number of surface finishes, including rough-sawn, kerfed rough-sawn, brushed, Texture 1-11, and reverse board-and-batten. These panels are best adapted to stain finishes.

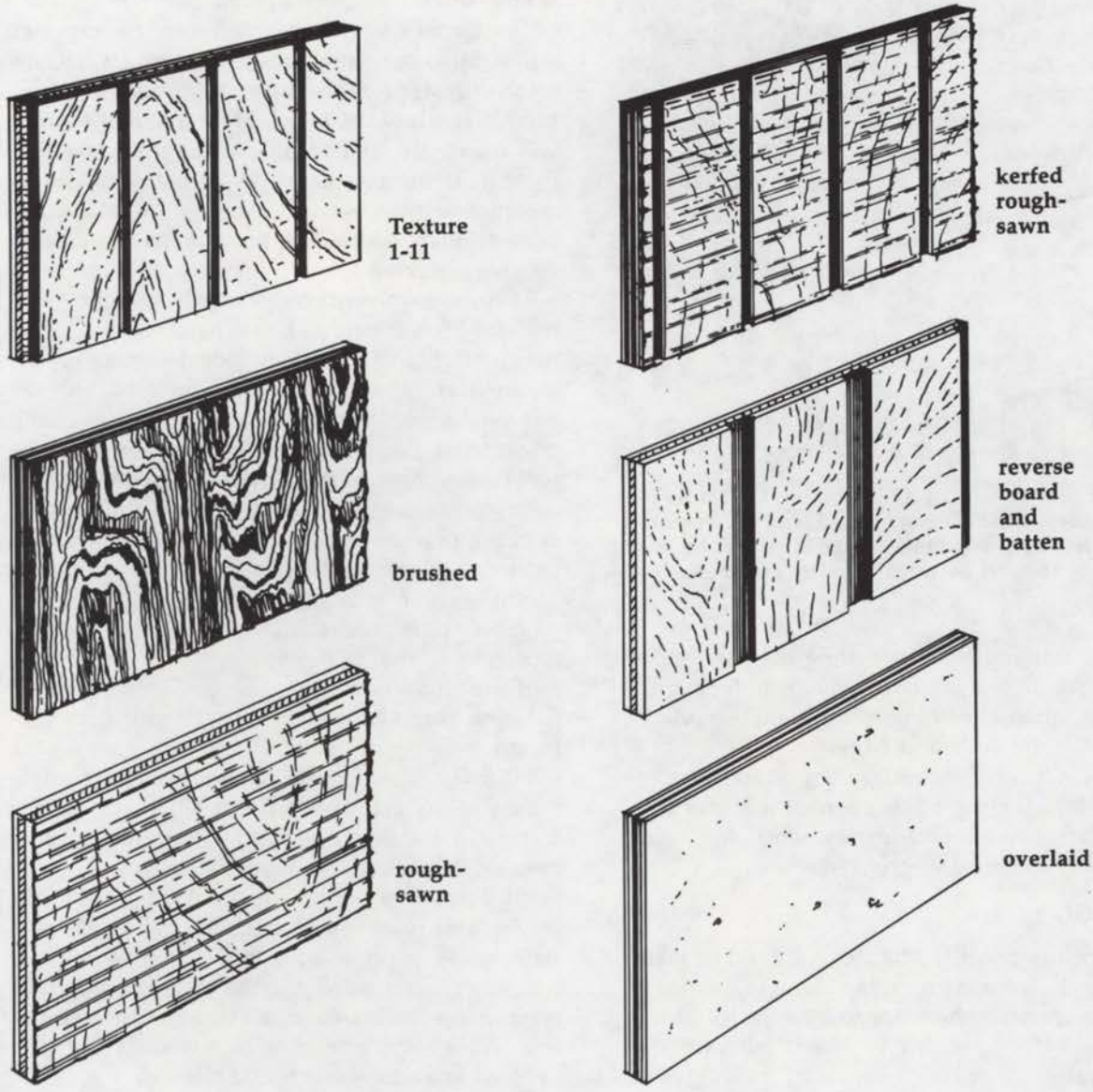
Most structural panel types are available with a medium-density overlay, which is a resin-impregnated fiber sheet, glued to one or both faces. Overlaid panels are intended to be painted with any high-quality exterior house paint system.

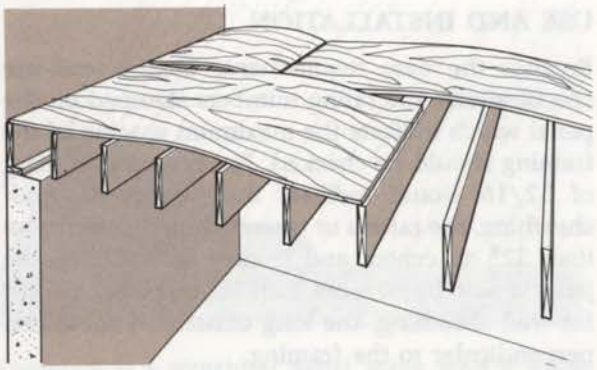
High-density overlaid panels are also available for special uses, such as reusable concrete forms.

USE AND INSTALLATION

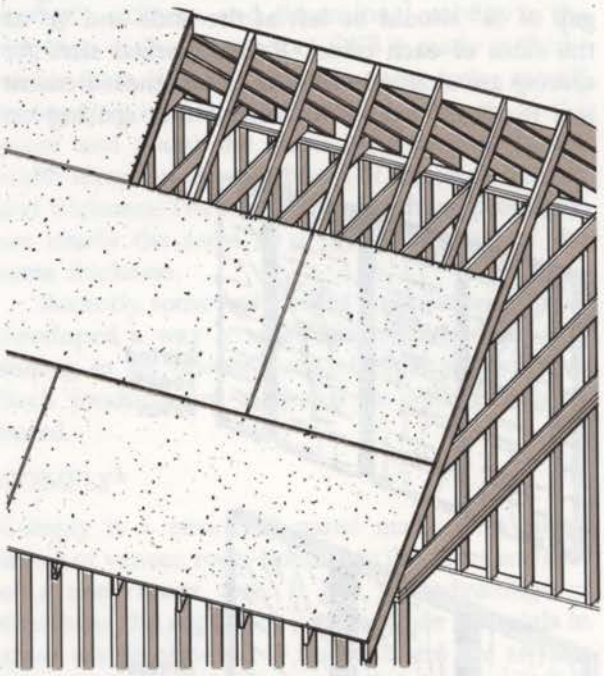
Because the new requirements include end-use specifications, the rating numbers stamped on the panel which indicate the maximum spacing of the framing should be checked. For example, a rating of 32/16 would indicate that for use as roof sheathing, the rafters or trusses should be no more than 32″ on center, and if used for subfloor, the joists should be no more than 16″ on center. Except for wall sheathing, the long dimension should be perpendicular to the framing.

The specifications include a gap at the ends and edges of the panel to allow for expansion, unless recommended otherwise by the manufacturer. For example, if used for roof sheathing, a gap of ⅛″ should be left at the ends and ¼″ at the sides of each panel. Panels marked *sized for spacing* are available with an actual measurement less than 48″ by 96″ to permit this spacing on





If panels are not spaced at the joints, an increase in humidity or other moisture problem will cause the sheets to expand and buckle between framing members or even pull nails and raise off the framing.



For both roof sheathing and subfloor, the joints between panels should be staggered, and the required spacing left between sheets. Edge clips can be used to provide support between framing members.

standard framing without cutting the panels. The spacing for a combination subfloor-underlayment or combination sheathing-siding panel should be ⅛″ at both the ends and edges.

Some panels require edge support such as clips or blocking. For the application of a single deck (combination subfloor-underlayment), the edges are usually tongue-and-grooved.

STORAGE

In storing any panel product, care should be taken to prevent damage from moisture and rain. If necessary, panels which are to be kept for only a few days before use can be stored outdoors if a good protective covering, such as polyethylene film, tarpaulin, or other waterproof material is used. The stack of panels should be loosely wrapped to prevent moisture condensation under the cover. Panels to be stored for a long period should be stacked flat inside a dry, covered storage area.

FINISHING

Since all panel products tend to be more absorbent at the edges, all edges of the panels should be sealed to minimize possible moisture damage. Both blind and exposed edges should be sealed. Sealing is easiest while the panels are stacked. Panels cut during construction should be resealed.

Panels to be painted or those to be concealed, such as sheathing, should be edge-sealed with a liberal brush coat of exterior house paint primer. In the case of textured panels to be stained, a liberal coat of water-repellant preservative that is compatible with the final finish should be applied. Horizontal edges, particularly lower drip edges of siding, should be given special care.

Face-checking of plywood can be expected when stains or natural finishes are used. Checking affects the appearance but not the bond or structural strength of the panel. More frequent staining will reduce the amount of checking but not eliminate it. If the panels are to be painted, using a medium-density overlaid panel is often less expensive than taking the precautions required to prevent checking.

Semi-transparent stains emphasize the grain pattern, texture, and natural characteristics in the panels. They will do little to hide defects or repairs in the surface, so they should be used only on panels designed for a stained finish. Any semi-transparent finish should be tested on a representative sample of the panels to demonstrate the color contrasting characteristics and the finished appearance. The American Plywood Association recommends only oil-based semi-transparent stains.

Solid-color or heavy-bodied stains work well on most siding products. They tend to hide surface repairs and the color differences in the wood. Surfaces that have been repaired with plastic patching compound may not take any stain uniformly because the patch is not as porous as the wood in the panel face. Opaque stains tend to minimize the grain pattern but retain the surface texture of the product. They generally are more durable than semi-transparent stains.

If paint is used on structural panels, an all-acrylic latex paint system consisting of at least one stain-blocking prime coat and a companion top coat is recommended by the APA. Some paint systems use two coats of a stain-blocking primer or an oil or alkyd primer on those woods that tend to bleed extractives, such as redwood.